A STOCK IDENTIFICATION STUDY IN THE NORTHERN ALASKA PENINSULA SOCKEYE SALMON FISHERY, FROM HARBOR POINT TO STROGONOF POINT

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Scale pattern analysis was shown to be an effective tool for discriminating between Bristol Bay and North Peninsula stocks in the 2.3 age class in the North Peninsula sockeye salmon fisheries in 1988. This age class was the most abundant one in the 1988 North Peninsula fishery. Using scale pattern analysis in 1988, no evidence of interception of Bristol Bay sockeye salmon was found in the Harbor Point to Cape Seniavin areas in the time when interceptions were considered most likely. Alternatively, some evidence was found for interceptions in the Cape Seniavin to Strogonof Point fishery, with interceptions comprising up to 50% of the harvest in this area after July 5th -- when fishing was allowed northeast of the Three Hills Section. This change in boundary lines is considered the most likely explanation for the increased interception. In 1988, during first sampling of the Cape Seniavin to Strogonof Point fishery following this northeastern opening, an estimated 66% of the age 2.3 sockeye salmon were bound for Bristol Bay. Making assumptions about the other age classes and the fish represented by the sample, an estimated 45% of the Cape Seniavin to Strogonof Point harvest, after the opening northeast of the Three Hills Section, were fish of Bristol Bay origin. This translates to approximately 296,000 Bristol Bay bound sockeye salmon. Subsequently, a less detailed analysis of scale samples from the Cape Seniavin to Strogonof Point fishery in 1987 and 1989 was used to estimate the proportion of Bristol Bay sockeye salmon in major year classes immediately after the opening northeast of the Three Hills Section in these years. On July 5th, 1989, an estimated 36% of the sockeye salmon caught in the Cape Seniavin to Strogonof Point area were estimated to be of Bristol Bay origin. During the week containing July 7th, 1987, an estimated 25% of sockeye salmon in the Cape Seniavin to Strogonof Point fishery were estimated to be of Bristol Bay origin, with this estimated proportion climbing to 42% during the week containing July 14th.

INTRODUCTION

For several years, members of the Bristol Bay gillnet fleet (Area T fisheries) have maintained that sockeye salmon bound for Bristol Bay have been intercepted by fishermen licenced to fish in the districts of the North Peninsula area (Area M fisheries). There have been complaints by Area T fishermen of interceptions of Bristol Bay bound sockeye salmon southwest of Strogonof Point (see Figure 1.). In 1988, the managers of the North Peninsula area began a program of scale pattern analysis to allow identification of the stocks harvested in their area. Because the Bristol Bay area had such a program in place it became possible to combine the data from both areas and estimate the extent of the interceptions in the North Peninsula fisheries. In 1989, low returns to the Bear River System caused closures in these northern North Peninsula fisheries. Even so, a limited fishery provided a sample of scales that again permitted an estimate of the stock composition near Strogonof point after the opening of fishing northeast of the Three Hills Section. Finally, scales collected in 1987 that had previously not been analyzed were examined to allow estimates of the stock composition near Strogonof Point on July 7th and 14th, 1987 -- after the opening northeast of the Three Hills Section.

The North Peninsula is divided into two districts: the Northwestern District, from Moffet Point to Cape Sarichef, and the Northern District, from the Southern most tip of Moffet Point to Cape Menshikof. Drift gillnet gear is used throughout the North Peninsula, with setnet sites throughout the Northern District except the Three Hills Section and the Bear River Section. Seining is allowed in the Herendeen Bay Section and the Bear River Section. In June, the majority of the drift gillnet effort is in the South Unimak fishery outside of the North Peninsula area. After June, the majority of the drift gillnet effort is in the Port Moller to Strogonof Point fisheries in the North Peninsula (McCullough, *In Press*).

Our investigation involved an analysis of the patterns of the scales of sockeye salmon collected from the escapement of the specific Bristol Bay and North Peninsula systems, and subsequently the comparison of the patterns of these scales with the scales of fish harvested in selected North Peninsula fisheries. The analysis is based on the premise that the scales of fish of different stocks will be subtlety dissimilar; if so, statistical techniques can be used to determine the probability that a scale from the catch was from one of a limited number of stocks. When many scales from the catch are analyzed in this fashion, the number of fish from each stock can be estimated. This type of analysis has been used for many years to provide estimates of fishery stock composition in Alaskan sockeye fisheries (Marshall, et al; 1987). Our charge was two-fold: first to report on whether Bristol Bay stocks have scales dissimilar to North Peninsula stocks, so that scale pattern analysis can be used to estimate the proportion of Bristol Bay fish in the North Peninsula; and secondly, to generate these estimates, if possible.

Straty (1975) reviewed what was known at the time of his writing about the entry of Bristol Bay bound fish from test fishing and tagging studies. He concluded, "...it is clear that sockeye salmon bound for Bristol Bay do not follow a route close inshore, at least not westward of Cape Seniavin." He went on to state that, "Early tagging experiments in the vicinity of Cape Seniavin by Gilbert coastal waters. These results were confirmed by additional tagging studies carried out in the same waters by Rich (1926)."

Based on Straty's conclusions, we decided to focus our search for Bristol Bay stocks in the two northern-most subdistricts: Harbor point to Cape Seniavin, and Cape Seniavin to Strogonof Point. We first searched for the Ugashik stock. Because of its geographical proximity to the North Peninsula, we felt that this stock should be the most abundant of the Bristol Bay stocks in the North Peninsula catch. We reasoned also that Bristol Bay interceptions would likely be found early in the season, because the Bristol Bay timing. For example, from 1956 to 1975 the average date at which 50% of the Ugashik run had passed the counting tower in the Ugashik River was July 16th, and the average date at which 50% of the Egegik had passed the counting tower was July 10th. Similarly, the latest the Ugashik run had 90% passed a test fishery in the Ugashik River, during these years, ranged from July 18th to July 5th (P.R. Mundy and O.A. Mathisen, in an 1977 unpublished University of Washington technical report: Handbook of Bristol Bay Sockeye Salmon Management.). In our investigation we initially focused on the 1988 fishery, and looked for interceptions of Bristol Bay bound fish in North Peninsula fisheries before and during statistical weeks 26-29 (June 19th to July 16th). After examining the 1988 fishery in some detail, we examined scales from the 1989 and 1987 fisheries in the times and areas considered to have the highest potential for Bristol Bay interceptions, based on the 1988 results.

MATERIALS AND METHODS

Sockeye salmon from the escapement of four North Peninsula systems were sampled during the summer of 1988; these systems were Bear River, Sandy Lake, Ilnik Lagoon, and Meshik River. In 1988, a sample of fish harvested in Nelson Lagoon was collected and assumed to represent fish that would escape to the Nelson River. A subsample of approximately 100 or 200 scales from the stocks with a large component of the specified age class of each North Peninsula escapement of interest was digitized, and the resulting measurements recorded. (For age 2.2 and age 2.3 only Bear River and Nelson Lagoon stocks were considered from the North Peninsula). Scales were similarly selected and digitized for the Ugashik, Naknek and Egegik systems in Bristol Bay in 1988. In the 1989 and 1987 analysis, only the Ugashik system was considered, based on the results of the 1988 analysis.

The probability of selection of a scale in the sample from each escapement was approximately proportional to the number of fish counted in the escapement during the week the scale was collected. A partial description of the sampling can be found in McCullough (1989) and McCullough (*In Press*). The fishery sample was obtained from tenders that had operated in the statistical areas in question. The tenders were sampled at the Port Moller cannery in Port Moller. When possible, the entire sample for a week was collected on the Monday of that week. This sample was used to characterize the harvest for the statistical week beginning each Sunday.

Ages are reported here using European notation as described by Koo (1962). Dates are often referred to using ADF&G statistical weeks (McCullough, 1989; *In Press*). In 1988, the North Peninsula harvest was made up of age classes 1.3, 2.2, and

2.3 almost exclusively; only these age classes were considered as candidates for analysis. Initial aging of the 1988 samples for the North Peninsula stocks was done by the Kodiak staff of the Alaska Department of Fish and Game (ADF&G), while all Bristol Bay aging and all digitizing in 1988 was done by the Bristol Bay staff of ADF&G, in Anchorage. Because any differences in aging methods or in digitizing techniques could introduce disastrous biases, in each year only a single technician digitized all scales. In 1988 the same technician re-aged a sample 545 of the North Peninsula scales. The results of the re-aging can be found in Table 1.

Variable names follow the convention used in other ADF&G scale pattern work. These names are outlined in various internal ADF&G memoranda (e.g., an unpublished manuscript entitled: Programs for Performing A Linear Discriminant Function Analysis of Scale Patterns Data From Species With Freshwater Growth, by Robert Conrad, 1985) and can be found in Appendix Table 1. In all age classes, relative distances (i.e., the distance from one focus to another as a proportion of the width of the zone the foci resided in) were used rather than absolute distances (i.e. the distance in mm between foci). The number of variables under consideration was further reduced using stepwise discriminant analysis by means of the SAS procedure PROC STEPDISC (SAS Institute, 1987), and a different set of variables was adopted in each year and age class. For the actual fisheries mixture, the number of variables selected for the final classification model was restricted to 10 or fewer. After variable selection with stepwise discriminant analysis, box and whisker plots (Chambers, et al. 1983) were made of all selected variables, by stock. Variables with obvious pathology (e.g., negative distances or extreme outliers) were either corrected or excluded, and the variable selection process restarted.

Stock separation models were constructed using linear discriminant analysis using the method of Fisher (Johnson and Wichern, 1982). In 1988, polynomial and nonparametric models were tested because of an obvious lack of normality and potentially dissimilar covariance matrices. These models gave similar results to the linear discriminant analysis, so the simpler linear discriminant analysis was used following the convention used previously in sockeye salmon stock separation work by ADF&G. The nearly-unbiased classification matrix, or "confusion matrix," was generated using the Lachenbruch's holdout procedure (Johnson and Wichern, op. cit.)

In 1988, the suitability of an age class for estimation of proportional Bristol Bay vs. North Peninsula compositions of the catch was judged based on classification accuracy, the Mahalanobis distance (Morrison, 1976) between stocks, and the relative importance of the age class in the harvest.

In 1988, *a priori*, or prior, probabilities for Bristol Bay stocks were set to low values (e.g., total prior probability for all Bristol Bay stocks summing to .10). This was based on the reasoning that the burden of proof went to the claim that Bristol Bay fish were being intercepted in the North Peninsula following the results of Straty (op. cit.), as discussed above. In fact, separation was adequate in the actual age classes examined in detail, and equal priors gave nearly the same results as when low prior probability was given to Bristol Bay stocks. In all years, the adjustment procedure of Cook and Lord (1978) was used on the final proportions, as is the custom in scale pattern analysis of Alaskan sockeye salmon (Marshal, et al. 1987). Following the Cook and Lord adjustment, estimated stock proportions were rounded to assure proportions were greater then zero and summed to one.

In 1988, a bootstrap (Efron, 1982) hypothesis test was constructed to assess the approximate statistical significance of the estimated proportion of Bristol Bay stocks in the North Peninsula fisheries, relative to the hypothesis that nonzero proportions were due to random misclassification error. Two sets of 150 scales from the age 2.3 Bear River and Nelson Lagoon samples were selected independently of scales used to develop the discriminant models. All of the Bear River scales, and 37 of the Nelson River scales were combined to give a mixture of approximately 80% Bear River "knowns", 20% Nelson Lagoon "knowns", and 0% Bristol Bay "knowns". From this mixture a sample of 100 scales was selected randomly, with replacement, and classified using the discriminant function used to classify the fishery samples. The proportion of the known mixture classifying to Bristol Bay was recorded, and the process was replicated 1000 times. This resulted in a distribution of estimated proportions of fish classifying to Bristol Bay, when the true proportion was in fact 0. This distribution is subsequently referred to as the bootstrap distribution. To simplify the computation, the Cook and Lord procedure was not used. (It took approximately 6 hours using SAS on a Compaq 386/20 computer with a 80386 coprocessor to generate this bootstrap distribution.) Following the development of the distribution of the estimated proportion classifying to Bristol Bay from the mixture known to contain 0% Bristol Bay scales, approximate P-values were assigned to the estimated Bristol Bay component from each North Peninsula fishery studied, based on the bootstrap distribution of proportions classifying to Bristol Bay before the Cook and Lord adjustment.

RESULTS

The 1988 Fishery

The weekly North Peninsula harvest and the estimated proportion of each age class in the catch based on scale pattern aging are listed in Table 2. Notice from this table that the 2.2 and 2.3 age classes made up the majority of the harvest in all weeks in the Harbor Point to Strogonof Point fishing districts; the proportion of age 2.x sockeye salmon ranged from a low of 65% (Harbor Pt. to Cape Seniavin Fishery, statistical week 23-24) to a high of 95% (Harbor Pt. to Cape Seniavin Fishery, statistical week 35). The estimated age composition of the escapement of Bristol Bay stocks in 1988 is shown together with the age composition of North Peninsula stocks and early harvest in the North Peninsula in Table 3. Because of the large numbers of 2.2 and 2.3's in the catch, we concluded that only Bristol Bay stocks with a large 2.2 or 2.3 component were potentially intercepted in large numbers in the North Peninsula fisheries. This left Ugashik, Naknek, and Egegik as potential candidates for further study of these age classes. This agrees with what would be expected based on geography, as these are the three Bristol Bay stocks closest to the North Peninsula fishery. Based on age classes alone, we feel confident that the present evidence would not support the claim that any Bristol Bay stocks, other than possibly the three immediately to the northeast (this possibility to be discussed below), were intercepted in large numbers in the North Peninsula sockeye salmon fisheries in 1988.

The Analysis of the 1988 2.2 Age Class:

Because of the low occurrence of this age class in North Peninsula stocks other than Nelson Lagoon and Bear River, only these two stocks were considered from the North Peninsula; in the initial phases of the analysis, only Ugashik stock was included from Bristol Bay. The Mahalanobis distance and the confusion matrix for an initial model is given in Table 4a and 4b. This model used 14 variables including fish length which could not be used to actually classify sockeye salmon caught in a gillnet fishery. Notice this three-way model resulted in a fair amount of confusion between Ugashik and Nelson River, with 14% of scales of the Nelson Lagoon stock classified to the Bristol Bay Ugashik stock. Based on these results, we decided to not pursue scale pattern analysis for this age class, for the 1988 catch, until the results of the initial analysis of the 2.3 age was finished. We decided to direct efforts to 2.3 age class, if this age class gave better classification accuracy.

The Analysis of the 1988 2.3 Age Class:

In the initial phases of the analysis, Ugashik stock from Bristol Bay was included in a model with Nelson Lagoon and Bear River. This model showed greater promise than the 2.2 age class. Tables 5, 6a and 6b give the Mahalanobis distance and the confusion matrices for a model containing seven classification variables. Table 7 gives this model. The overall classification accuracy (using Lachenbruch's holdout procedure) was 88%. Bear River and Nelson Lagoon classified 2%, and 6%, respectively, to the Ugashik system, and Ugashik classified 8% and 20%, respectively, to the two North Peninsula systems.[1]

Because of the large proportions of age 2.3 in the fisheries of interest, and because of the encouraging results separating Ugashik from the North Peninsula stocks with a large 2.3 component, Naknek and Egegik stocks were also included in the model. A model with five stocks would be expected to have a fair amount of misclassification, although even with all five stocks the model was showing 78% accuracy. In the five-way model, Naknek scales classified to North Peninsula systems 25% of the time, while 9% and 7% of the Bear River and Nelson Lagoon scales, respectively, classified to Naknek. See Table 8 for the confusion matrix.

The scales from the harvest were classified from five selected harvest strata: two early periods in the Harbor Point to Cape Seniavin area, and three periods in the Cape Seniavin to Strogonof Point area. The two periods in the Harbor Point to Cape Seniavin fishery were combined statistical weeks 26-27 (June 19th - July 2nd) and statistical week 28 (July 3rd - July 9th). The three periods in the Cape Seniavin to Strogonof Point were combined statistical weeks 26-27, statistical week 28, and statistical week 29 (July 10th - July 16th). Even though the northern-most fisheries lying above the Three Hills Section opened during statistical week 28, the first sample that contained these fish was taken at the beginning of statistical week 29. The notable results are that the Harbor point to Cape Seniavin scales classified over 96% to Bear River and Nelson Lagoon (slightly less in the five-way models for both of the early periods). In both cases the proportion classifying to Bristol Bay is within the range of expected misclassification error. (approximate bootstrap P-val>.5). However, in the Cape Seniavin to Strogonof Point fishery, using the three stock model, the percentage of North Peninsula bound sockeye salmon was estimated to be 90% and 85% the first

[1] The high misclassification of Ugashik is due to the high prior probability placed on North Peninsula stocks. This is adjusted for by the Cook and Lord procedure.

two periods, (approximate bootstrap P-val=.01 and .00, respectively) but dropped to only 34% the third period (approximate bootstrap P-val=.00). This third period corresponds to a sample after fishing was opened northeast of the Three Hills Section.

Estimated 1988 Bristol Bay Contribution

We made the assumption that all age classes except 2.2 and 2.3 were fish of North Peninsula origin, and assumed that the age 2.2 and 2.3 had a similar distribution of origin. Further, we assumed that those weeks where the proportion of age 2.3 fish of Bristol Bay origin was not statistically significantly different from zero (P-val > .05), as judged by the bootstrap method, and for those weeks with no sampling, the entire catch was of North Peninsula origin. This resulted in estimating that all fish except those in the Cape Senivian to Strogonof Point fisheries in statistical weeks 26-29 were of North Peninsula origin. The fishery opened northeast of the Three Hills Section during the middle of statistical week 28, but the scale sample for that week came from the Monday of that week -- before the opening. For this reason the proportion of age 2.3 fish of Bristol Bay origin was assumed to be the same as the following week's estimate -- perhaps overstating the extent of the Bristol Bay stock contribution to the North Peninsula fishery. Table 9 gives these results. Using the methods and assumptions described above, we estimated that approximately 296,000, or slightly less than 24% of the Harbor Point to Strogonof Point sockeye salmon harvest was fish of Bristol Bay origin in 1988.

North Peninsula Stocks in the Ugashik District

A five-stock model was developed to investigate the possibility that there were large interceptions of North Peninsula age 2.3 fish in the Ugashik District. This model had fair accuracy (74% accuracy with equal priors). Because of the large number of stocks and the relatively small sample sizes, the Cook and Lord adjustment was not used here. Less than 5% of the sampled fish classified to the North Peninsula in each of the three periods studied. The exact estimates were 5% North Peninsula fish intercepted in pooled statistical weeks 23-28 (May 29th - July 9th), 1% intercepted in statistical week 29 (July 10th -16th), and 3% intercepted in statistical week 30 (July 17th - 23). While resources were not sufficient to generate approximate bootstrap significance probabilities here, these results seem perfectly consistent with the hypothesis that there were no North Peninsula fish harvested in the Ugashik District in 1988. Assuming that 5% of the Ugashik district harvest during statistical weeks 23 - 30 was of North Peninsula origin in 1988, then approximately 75,000 sockeye salmon of North Peninsula were intercepted in the Ugashik district. It is important to realize that these results are also consistent with the hypothesis that 75,000 North Peninsula sockeye salmon were intercepted in the North Peninsula. Interceptions of North Peninsula stocks of 100,000 or more sockeye salmon would be very hard to detect. This is because these North Peninsula fish would be diluted in almost 1.5 million sockeye salmon that were caught in the Ugashik district during these weeks, and both North Peninsula stocks have high misclassification in the five-stock model that was used.

The 1989 Fishery

In 1989, conservation considerations limited the Cape Seniavin to Strogonof Point fishery. The area northeast of the Three Hills Section was fished only during a single 18 hour opening on July 5th. Fish captured during this opening were sampled, and scales from age 2.2 fish were digitized. Similarly over 200 age 2.2 scales from each of the Bear River, Nelson Lagoon and Ugashik systems were used to construct a linear discriminant model. A two-stock model, pooling Bear River and Nelson Lagoon, performed well largely because most Ugashik scales showed "plus growth" after the final fresh water growth period, and this growth was absent in all North Peninsula scales examined. See Table 10 for the confusion matrix for the 1989 two-stock model. After the Cook and Lord adjustment, 44% of these age 2.2 fish from the Cape Seniavin to Strogonof Point are, caught during the 18 hour opening, classified to Bristol Bay. Because catches are summarized by statistical week, and because the samples from this 18 hour opening are not representative of the entire week, it is not possible to estimate what the number of Bristol Bay sockeye salmon intercepted in the Cape Seniavin to Strogonof Point in 1989. Noting that 80.7% of the harvest during this statistical week was of age 2.2 or 2.3 (James McCullough, personal communication), and assuming a similar age composition for the 18 hour opening, and assuming the interception pattern was similar for age 2.2 and 2.3, and assuming no interceptions of any other age class, then approximately 36% of the harvest during the 18 hour opening was sockeye salmon of Bristol Bay origin. This surely overestimates what the actual interception rate was for this week, as only 18 hours were open in the area with the highest interceptions. This might be thought of as a reasonable estimate of what the interception rate would have been, if the Strogonof Point area had been open all week.

The 1987 Fishery

Previously unanalyzed scales from 1987 were digitized from the 2.3 age class. The 2.3 age class made up 49.3% of the Cape Seniavin to Strogonof Point sockeye salmon harvest in 1987, although the escapement of Nelson and Bear Rivers comprised 2.8% and 31.2% of this age class, respectively (McCullough, 1989). Slightly over 200 scales from the escapements of Nelson Lagoon, Bear River, and Ugashik systems were digitized, and discriminant models were constructed as described above. A three-stock model had 72% accuracy, with Ugashik misclassifying to Bristol Bay Stocks 28% of the time, and Bear River and Nelson Lagoon misclassifying to Ugashik 8% and 16% of the time, respectively. A simpler two stock model had 80% accuracy with Ugashik and the North Peninsula stocks each misclassifying approximately 20% of the time (see Table 11 for this confusion matrix). Using this model, on a sample of scales collected on July 7th (statistical week 28), after the opening northeast of the Three Hills Section, an estimated 41% of the age 2.3 sockeye salmon caught south of Strogonof Point were of Bristol Bay origin. On July 14th the estimated interception of Bristol Bay stock contribution had climbed to 71%. Assuming that only age 2.2 and 2.3 age fish were potentially of Bristol Bay origin, and that 2.2 aged sockeye had a similar interception pattern, and that interceptions occurred only in statistical weeks 28 and 29, then in 1987 approximately 150,000 Bristol Bay bound sockeye salmon were intercepted in the North Peninsula fishery in the vicinity on Strogonof Point. This figure may understate the actual interception, as there were likely to be nonzero interception rates in weeks not examined.

DISCUSSION

The first goal was to find out whether scale pattern analysis can be used to discriminate between stocks in the North Peninsula sockeye salmon fisheries. When combined with an analysis of age classes, multivariate statistical methods have been shown here to be a workable means of allocating the North Peninsula sockeye salmon harvest to management area of origin. With the resources committed to this project in 1988, the accuracy and precision seem to produce results that meet or exceed present management needs. We are now in a position to make some definite statements about stock compositions in the North Peninsula fisheries.

First, there is no evidence that substantial numbers of Bristol Bay sockeye salmon were intercepted in Harbor Point to Cape Seniavin fishery in 1988. Indeed these data suggest that age 2.3 sockeye salmon in these fisheries were exclusively of North Peninsula origin. Three, four, and five-stocks models yielded similar results, although the precision and accuracy declined as the number of stocks increased.

Second, there is evidence that Bristol Bay stocks were present at low levels in the Cape Seniavin to Strogonof Point fishery in the first two periods 1988, corresponding to fishing south of the northern boundary of this area. There is also strong evidence that Bristol Bay stocks were present in 1988 in high levels after fishing North of Three Hills Section was allowed, beginning on the 5th of July. We estimated that approximately 296,000 sockeye salmon were intercepted during the periods studied. These periods covered 91% of the harvest in the Cape Seniavin to Strogonof Point fishery in 1988. This estimate may slightly overstate the extent of the interceptions, as not all fish caught in statistical week 28 were caught after the opening northeast of the Three Hills Section. Alternately, we may have slightly understated the interception by assuming zero interceptions in all weeks in which the estimated interception rate was low. Note that the conclusions from this study are very different from the ones drawn by Straty (1975), the only source of information on the North Peninsula sockeye salmon stock composition before now.

Inter-year variation in fish migration, fleet deployment, or inter-year variation in many other factors may cause the results of a single-year study to be very misleading. Our study focused on the year 1988, but our examination of the Cape Seniavin to Strogonof Point fishery, after the opening of the Three Hills Section, in 1989 and in 1987, reveals the same pattern -- that of 25% to 50% interceptions of Bristol Bay sockeye salmon bound for the Ugashik system in the vicinity of Strogonof Point.

LITERATURE CITED

Chambers, John M., William S. Cleveland, Beat Kleiner, and Paul A. Tukey. 1983. Graphical methods for data analysis. Wadsworth International. Belmont, California.

Cook, Rodney C., Gary E. Lord. 1978. Identification of stocks of Bristol Bay sockeye salmon, *Oncorhynchus nerka*, by evaluating scale patterns with a polynomial discriminant method. U.S. Fish and Wildl. Serv., Fishery Bulletin. Vol. 76 Number 2. 414-423.

Efron, B. 1982. The Jackknife, The Bootstrap, and other resampling plans. SIAM. Philadelphia.

Johnson, Richard A., Dean W. Wichern. 1982. Applied Multivariate Statistical Analysis, 2nd ed. Prentice-Hall. Englewood Clifs, New Jersey.

Koo, T. S. 1962. Age and growth studies of red salmon scales by graphical means. Studies of Alaska Red Salmon. Univ. of Washington Publ. in Fisheries, New Ser. 1:51-100. University of Washington Press, Seattle.

Marshal, Scott, et al, 1987. Application of scale patterns analysis to the management of Alaska's sockeye salmon (*Oncorhynchus nerka*) fisheries. Canadian Special Publication of Fisheries and Aquatic Sciences (96): Sockeye Salmon, Population Biology and Future Management.

McCullough, James N. *In Press*. Alaska Peninsula-Aleutian Islands Area Catch and Escapement Statistics, 1988. Alaska Department of Fish and Game Technical Fisheries Report. Alaska Dept. of Fish and Game. Juneau Ak.

McCullough, James N. 1989. Alaska Peninsula-Aleutian Islands Area Catch and Escapement Statistics, 1987. Alaska Department of Fish and Game Technical Fisheries Report 89-20. Alaska Dept. of Fish and Game. Juneau Ak.

Morrison, Donald, F. 1976. Multivariate statistical methods, 2nd ed. McGraw Hill. New York.

SAS Institute. 1987. SAS/STAT guide for personal computers, version 6. SAS Institute Inc. Cary NC.

Straty, Richard R. 1975. Migratory Routes of Adult Sockeye Salmon, *Oncorhynchus nerka*, in the Eastern Bering Sea and Bristol Bay. NOAA Technical Report NMFS SSrf-690. United States Department of Commerce.

Table 1. Agreement and disagreement in aging of scales between Kodiak staff which developed age class estimates for North Peninsula escapements, and the technician that developed age class estimates for Bristol Bay in 1988. Rows represent different North Peninsula systems, and columns, the ages of salmon in that system. The number at the top of the cell represents the number of scales agreed on, the number on the bottom the number disagreed on. The numbers to the right of the table represent the number of scales aged for the system represented by that row. The overall rate of disagreement was 4%, and the maximum rate of disagreement for any system was 4%.

	AGE				
	Unreadable	0.	1.	2.	
Ilnik Riv. Escapement	8 / 1	33 / 1	38 / 0	1 / 1	80
Meshik R. Escapement	3 / 0	26 / 0	8 / 1	2 / 1	40
Sandy Riv. Escapement	3 / 0	1 / 0	36 / 0	0 / 0	40
Bear Riv. Escapement	7 / 0	0 / 0	4 / 7	182 / 7	200
Nelson La. Catch	19 / 2	0 / 1	88 / 1	76 / 0	185

Table 2. Detailed age composition estimates for the two northern-most North Peninsula fisheries in 1988.

Fishery	Statistical[2] Week	Estimated Age Component[3] 1.2	1.3	2.2	2.3	Total Catch
Harbor Pt. to Cape Seniavin	23-24	.02	.29	.01	.64	691
	25	.02	.24	.03	.69	5,829
	26	.01	.19	.04	.74	56,048
	27	.03	.20	.17	.58	81,889
	28	.02	.15	.09	.72	61,292
	29	.03	.21	.15	.60	20,425
	30	.01	.08	.22	.69	34,474
	31	.01	.08	.25	.65	27,480
	32	.00	.05	.22	.71	35,077
	33	.02	.09	.24	.65	54,311
	34	.01	.07	.24	.67	33,632
	35	.00	.05	.24	.71	58,542
	36-37	.00	.04	.32	.62	29,028
Cape Seniavin to Strogonof Pt.	26-27	.08	.16	.23	.48	100,355
	28	.07	.15	.22	.55	395,564
	29	.07	.18	.29	.44	183,100
	30	.07	.19	.23	.49	35,224
	31	.03	.15	.30	.51	10,695
	32	.02	.09	.26	.62	9,227
	33	.01	.08	.21	.69	2,618
	34-37	.01	.11	.15	.72	9,213

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[2]Statistical weeks are used here to maintain compatibility with other North Peninsula Fishery reports. The statistical week begins on a Sunday, and ends on the following Saturday. In 1988 statistical week 24 ran from June 5th to June 11th. Statistical week 28 ran from July 3rd to July 9th, and so on.

[3]Proportions for all age classes do not necessarily add to one because minor age classes are omitted.

Table 3. Estimated major age classes (1.2, 1.3, 2.2, and 2.3) of Bristol Bay and North Peninsula escapements in 1988, with age classes of selected fisheries.

System	Estimated Age Classes[5] 1.2	1.3	2.2	2.3	Major Ages	Escapement or Harvest
Bristol Bay System Escapements						
Kvichak	38%	41%	17%	2%	99%	4,065,216
Branch	50%	37%	10%	0%	98%	194,630
Naknek	28%	26%	19%	24%	96%	1,037,862
Egegik	6%	27%	48%	14%	95%	1,612,680
Ugashik	24%	10%	30%	28%	92%	642,972
Wood	35%	61%	0%	0%	99%	866,778
Igushik	27%	70%	0%	1%	99%	170,454
Nuyakuk	21%	74%	0%	0%	95%	319,992
Snake	NA	NA	NA%	NA%	NA%	
Nush-Mul.	3%	95%	0%	0%	99%	163,210
Togiak	3%	95%	0%	0%	99%	309,012
North Peninsula System Escapements						
1. Bear	0%	5%	41%	45%	90%	
2. Nelson	17%	20%	18%	43%	99%	
3. Sandy	62%	34%	2%	0%	99%	
4. Ilnik	6%	43%	0%	4%	53%	
5. Meshik	0%	9%	0%	1%	12%	
North Peninsula Harvest Before July 12th (stat. week 29)						
Harbor Pt. to Cape Seniavin	2%	20%	9%	67%	98%	226,174
Cape Seniavin to Strogonof Point	7%	16%	25%	49%	98%	679,019

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[4]Proportions for all age classes do not necessarily add to one because minor age classes are omitted.

Table 4a. Mahalanobis distances between group centroids for 2.2 age class in 1988.

From System	Bear	Nelson	Ugashik
Bear	0	7.13457	12.84789
Nels	7.13457	0	3.86616
Ugas	12.84789	3.86616	0

Table 4b. Confusion matrix -- number of observations and percent classified into each system for 2.2 age class in 1988.

From System	Bear	Nelson	Ugashik	Total
Bear	93	7	0	100
%	93.00	7.00	0.00	100.00
Nelson	14	72	14	100
%	14.00	72.00	14.00	100.00
Ugashik	3	30	167	200
%	1.50	15.00	83.50	100.00
Total	110	109	181	400
%	27.50	27.25	45.25	100.00
Priors	0.3333	0.3333	0.3333	
		Error Count		
Rate	0.0700	0.2800	0.1650	0.1717
Priors	0.3333	0.3333	0.3333	

Table 5. Mahalanobis distance between centroids for discriminant model using age 2.3 scales from Bear River, Nelson Lagoon, Ugashik, Naknek, and Egegik stocks in 1988.

From System	Bear	Egegik	Naknek	Nelson	Ugashik
Bear	0	14.37937	5.66009	6.60081	8.82944
Egeg	14.37937	0	5.38284	9.54457	5.18916
Nakn	5.66009	5.38284	0	4.31787	1.01619
Nels	6.60081	9.54457	4.31787	0	6.14780
Ugas	8.82944	5.18916	1.01619	6.14780	0

Table 6a. Confusion matrix -- number of observations and percent classified into each system for age 2.3 sockeye salmon scales from Bear River, Nelson Lagoon, and Ugashik stocks in 1988. Notice, unlike the actual classification model, this model uses equal priors.

From System	Bear	Nelson	Ugashik	Total
Bear	172	17	10	199
%	86.43	8.54	5.03	100.00
Nelson	15	171	14	200
%	7.50	85.50	7.00	100.00
Ugashik	9	14	177	200
%	4.50	7.00	88.50	100.00
Total	196	202	201	599
%	32.72	33.72	33.56	100.00
Priors	0.3333	0.3333	0.3333	

		Error Count		
Rate	0.1357	0.1450	0.1150	0.1319
Priors	0.3333	0.3333	0.3333	

Table 6b. Confusion Matrix after adjusting prior probabilities to give more weight to North Peninsula.

	Bear	Nelson	Ugashik	Total
Bear	179	18	2	199
%	89.95	9.05	1.01	100.00
Nelson	15	179	6	200
%	7.50	89.50	3.00	100.00
Ugashik	16	43	141	200
%	8.00	21.50	70.50	100.00
Total	210	240	149	599
%	32.06	40.07	24.87	100.00
Priors	.4500	.4500	.1000	

		Error Count		
Rate	.1005	.1050	.2950	0.1220
Priors	.4500	.4500	.1000	

Table 7. Preferred Linear Discriminant Function for Age 2.3 Sockeye to discriminate Bear River, Nelson Lagoon, and Ugashik Stocks.

$$\text{Constant} = -.5\ \bar{X}'\ \text{COV}_j^{-1}\ \bar{X}_j \qquad \text{Coefficient Vector} = \text{COV}^{-1}\ \bar{X}_j$$

	SYSTEM		
	Bear	Nelson	Ugashik
CONSTANT	-419.27172	-436.76573	-438.08502
V27	-7.25731	-8.18954	-8.74897
V31	37.42583	39.36030	38.15424
V47	264.09785	263.82972	264.64352
V56	347.21122	367.30853	336.10997
V57	32.07667	33.75539	35.09737
V62	0.67137	0.85469	0.75098
V91	9.22353	-22.67748	16.53064

Table 8. Confusion matrix -- number of observations and percent classified into each system for age 2.3 sockeye salmon scales from Bear River, Nelson Lagoon, Ugashik, Egegik, and Naknek stocks. Notice, unlike the actual classification model, this model uses equal priors.

	Bear	Egegik	Naknek	Nelson	Ugashik	Total
Bear	154	0	18	22	5	199
%	77.39	0.00	9.05	11.06	2.51	100.00
Egegik	8	161	16	4	11	200
%	4.00	80.50	8.00	2.00	5.50	100.00
Naknek	24	18	79	25	53	199
%	12.06	9.05	39.70	12.56	26.63	100.00
Nelson	16	3	14	161	6	200
%	8.00	1.50	7.00	80.50	3.00	100.00
Ugashik	3	13	48	14	122	200
%	1.50	6.50	24.00	7.00	61.00	100.00
Total	205	195	175	226	197	998
%	20.54	19.54	17.54	22.65	19.74	100.00
Priors	0.2000	0.2000	0.2000	0.2000	0.2000	

Error Count

Rate	0.2261	0.1950	0.6030	0.1950	0.3900	0.3218
Priors	0.2000	0.2000	0.2000	0.2000	0.2000	

Table 9. Estimated numbers of sockeye salmon in two North Peninsula fisheries, by area of origin.

Stat. Week	Harvest	Proportion of Age-Class From N. Pen. 1.x	2.x	Harvest of North Pen. Origin	Harvest of B. Bay Origin
Harbor Pt. to Cape Seniavin					
25	5,829	1	1	5,829	0
26	56,048	1	1	56,048	0
27	81,889	1	1	81,889	0
28	61,292	1	1	61,292	0
29	20,425	1	1	20,425	0
30	34,474	1	1	34,474	0
31	27,480	1	1	27,480	0
32	35,077	1	1	35,077	0
33	54,311	1	1	54,311	0
34	33,632	1	1	33,632	0
35	58,542	1	1	58,542	0
36-37	29,028	1	1	29,028	0
Cape Seniavin to Strogonof Pt.					
26-27	100,355	1	0.90	93,230	7,125
28	395,564	1	0.34[5]	194,539	201,025
29	183,100	1	0.34	94,882	88,217
30	35,224	1	1	35,224	0
31	10,695	1	1	10,695	0
32	9,227	1	1	9,227	0
33	2,618	1	1	2,618	0
34-37	9,213	1	1	9,213	0
	1,244,023			947,656	296,367

[5] From following week's scale pattern analysis. This statistical week the fishery opened north of the Three Hills Section in mid-week, but the scale sample was from the Monday before the opening. This proportion may overstate the actual Bristol Bay component.

Table 10. Confusion matrix -- number of observations and percent classified into each system for age 1989, 2.2 sockeye salmon scales from Bear River and Nelson Lagoon stocks pooled into a single stock labeled North Pen., and Ugashik stock labeled Bristol Bay.

From System	B. Bay	N. Pen.	Total
B. Bay	214	29	243
%	88.07	11.93	100.00
N. Pen.	0	504	504
%	7.50	100.00	100.00
Total	214	533	747
%	28.65	71.35	100.00
Priors	.45	.55	

		Error Count	
Rate	0.1193	.0000	0.0537
Priors	.45	.55	

Table 11. Confusion matrix -- number of observations and percent classified into each system for age 1987, 2.3 sockeye salmon scales from Bear River and Nelson Lagoon stocks pooled into a single stock labeled North Pen., and Ugashik stock labeled Bristol Bay.

From System	B. Bay	N. Pen.	Total
B. Bay	184	51	235
%	78.30	21.70	100.00
N. Pen.	89	350	439
%	20.27	79.73	100.00
Total	273	401	674
%	40.50	59.50	100.00
Priors	.53	.47	

			Error Count
Rate	0.2170	.2027	0.2103
Priors	.53	.47	

Tables 12a, 12b and 12c. Proportions and numbers of sockeye salmon estimated to be of Ugashik stock in the Cape Seniavin to Strogonof Point fishery by year and ADF&G statistical week. Note that the area northeast of the Three Hills Section opened in statistical week 28 in 1987 and 1988, but opened in statistical week 27 in 1989.

Table 12a. Estimated proportion of major age class of Ugashik stock.

Statistical Week	1987 (age 2.3)	1988 (age 2.3)	1989 (age 2.2)
26	n.d.[7]	10%	n.d.
27	n.d.	10%	small
28	41%	66%	n.d.
29	71%	66%	n.d.
30	n.d.	n.d.	n.d.

Table 12b. Estimated proportions of sockeye salmon harvests (all age classes) estimated to be of Ugashik stock.

Statistical Week	1987	1988	1989
26	n.d.	7%.	n.d.
27	n.d.	7%	small[8]
28	25%	50%	n.d.
29	42%	48%	n.d.
30	n.d.	n.d.	n.d.

Table 12c. Estimated interception of sockeye salmon of Ugashik stock.

Statistical Week	1987	1988	1989
26	n.d.		n.d.
27	n.d.	7,125[9]	unknown
28	68,798	201,025	0
29	81,135	88,217	0
30	n.d.	n.d.	0

[7]n.d. stands for no data.

[8]While 36% of the harvest from a single 18 hour opening in this week was estimated to Bristol Bay bound, the proportion for the entire week can not be estimated, but must be much less than 36%, but based on 1988 results it is likely larger than 7%.

[9]This figure is for statistical weeks 26 and 27 combined.

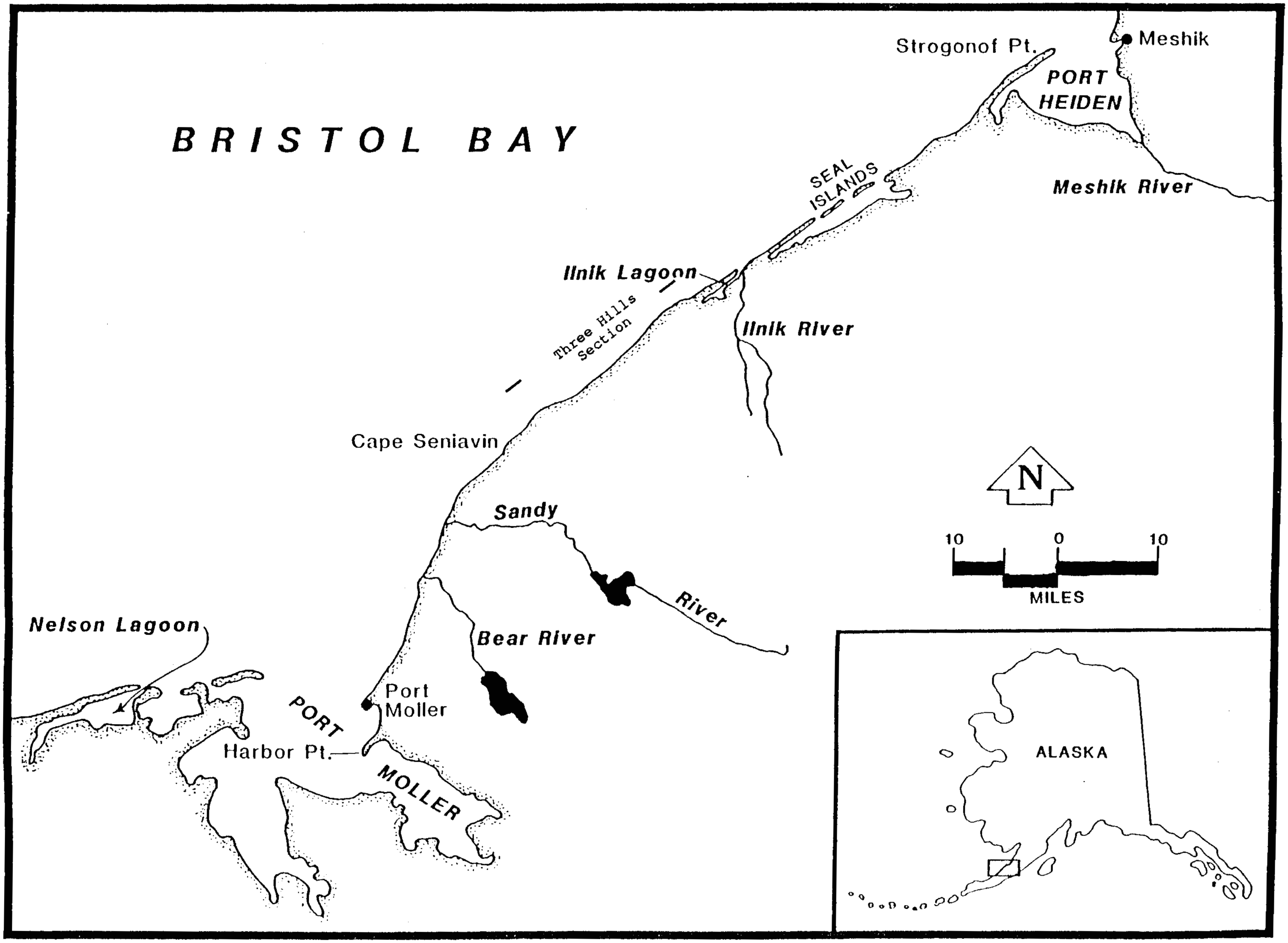

Figure 1. Harbor Point to Strogonof Point area.

APPENDICES

Appendix Table 1. List of scale variables used in constructing linear discriminant models. Ci refers to the distance from the beginning of the designated zone to the ith circulus.

Variable	1st Freshwater Annular Zone
v1	Number of circuli
v2	Width of zone
v3 (v16)	Distance, scale focus to circulus 2 (C0-C2)
v4	Distance, C0-C4
v5 (v18)	Distance, C0-C6
v6	Distance, C0-C8
v7 (v20)	Distance, C2-C4
v8	Distance, C2-C6
v9 (v22)	Distance, C2-C8
v10	Distance, C4-C6
v11 (v24)	Distance, C4-C8
v12	Distance, from end of 4th circulus to end of zone
v13 (v26)	Distance, from end of 2nd circulus to end of zone
v14	Distance, C2 to end of zone
v15	Distance, C4 to end of zone
v16 to v26	Relative widths, (v3 to v13)/v2
v27	Average interval between circuli, v2/v1
v28	Number of circuli in first 3/4 of zone
v29	Maximum distance between 2 consecutive circuli
v30	Relative width, v29/v2

Variable	2nd Freshwater Annular Zone
v31	Number of circuli
v32	Width of zone
v33 (v46)	Distance, end of 1st annular zone to C2
v34	Distance, end of 1st annular zone to C4
v35 (v48)	Distance, end of 1st annular zone to C6
v36	Distance, end of 1st annular zone to C8
v37 (v50)	Distance, C2-C4
v38	Distance, C2-C6
v39 (v52)	Distance, C2-C8
v40	Distance, C4-C6
v41 (v54)	Distance, C4-C8
v42	Distance, from end of 4th circulus to end of zone

Appendix Table 1 (continued).

Variable	2nd Freshwater Annular Zone
v43 (v56)	Distance, from end of 2nd circulus to end of zone
v44	Distance, C2 to end of zone
v45	Distance, C4 to end of zone
v46 to v56	Relative widths, (v33 to v43)/v32
v57	Average interval between circuli, v32/v31
v58	Number of circuli in first 3/4 of zone
v59	Maximum distance between 2 consecutive circuli
v60	Relative width, v59/v32

Variables	Freshwater Plus Growth
v61	Number of circuli
v62	Width of zone

Variables	All Freshwater Zones
v63	Total number annular circuli
v64	Total width of annular zone
v65	Total number of freshwater circuli
v66	Total width of freshwater zone, v2+v32+v62
v67	Relative width, v2/v66
v68	Relative width, v62/v66
v69	Relative width, v32/v66

Variable	1st Marine Annular Zone
v70	Number of circuli
v71	Width of zone
v72 (v90)	Distance, end of freshwater growth to C3
v73	Distance, end of freshwater growth to C6
v74 (v92)	Distance, end of freshwater growth to C9
v75	Distance, end of freshwater growth to C12
v76 (v94)	Distance, end of freshwater growth to C15
v77	Distance, C3-C6
v78 (v96)	Distance, C3-C9
v79	Distance, C3-C12
v80 (v98)	Distance, C3-C15
v81	Distance, C6-C9
v82 (v100)	Distance, C6-C12
v83	Distance, C6-C15
v84 (v102)	Distance, C9-C15
v85	Distance, from end of 6th circulus to end of zone
v86 (v104)	Distance, from end of 3rd circulus to end of zone

Appendix Table 1 (continued).

Variable	1st Marine Annular Zone
v87	Distance, C3 to end of zone
v88	Distance, C9 to end of zone
v89	Distance, C15 to end of zone
v90 to v104	Relative widths, (v72 to v86)/v71
v105	Average interval between circuli, v71/v70
v106	Number of circuli in first 3/4 of zone
v107	Maximum distance between 2 consecutive circuli
v108	Relative width, v107/v71

Variable	All Marine Zones
v109	Width of 2nd marine zone
v110	Width of 3rd marine zone
v111	Total width of marine zones, v71+V109+V110
v112	Relative width, v71/v111
v113	Relative width, v109/v111